Novel Real Time Optics for Thin Film Materials Research - I

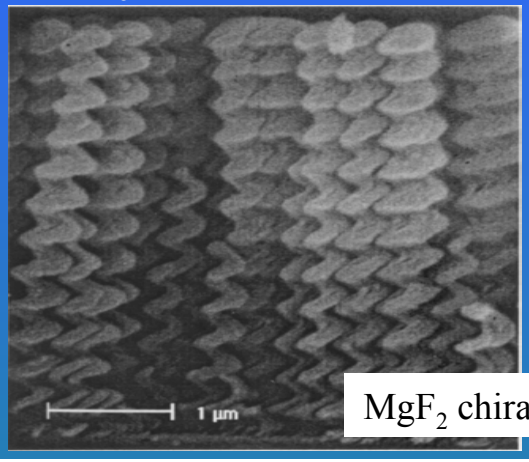
Robert W. Collins, The Pennsylvania State University, DMR-0137240

Introduction

- Novel real time optical probes of thin film deposition and nano/micro structural evolution expedite the development and optimization of new thin film materials and devices based on insights into the physical and chemical mechanisms of deposition.

Selected Scientific Highlight

- A unique dual rotating compensator multichannel ellipsometer developed earlier has been applied to measure sculptured thin films. Spectra (1.5 to 4.5 eV) in all 16 elements of the 4x4 Mueller matrices of these films have been acquired at high speeds. A *Mueller matrix* describes how incident beam polarization states are modified by a thin film.
- Chiral sculptured thin films exhibit resonances in their optical characteristics when the incident beam wavelength matches the pitch of the helices. These resonances arise due to the differences in index of refraction of the film for left and right circular polarization. The resonance positions show variations with angle of incidence that can be understood using a diffraction theory.



MgF_2 chiral STF

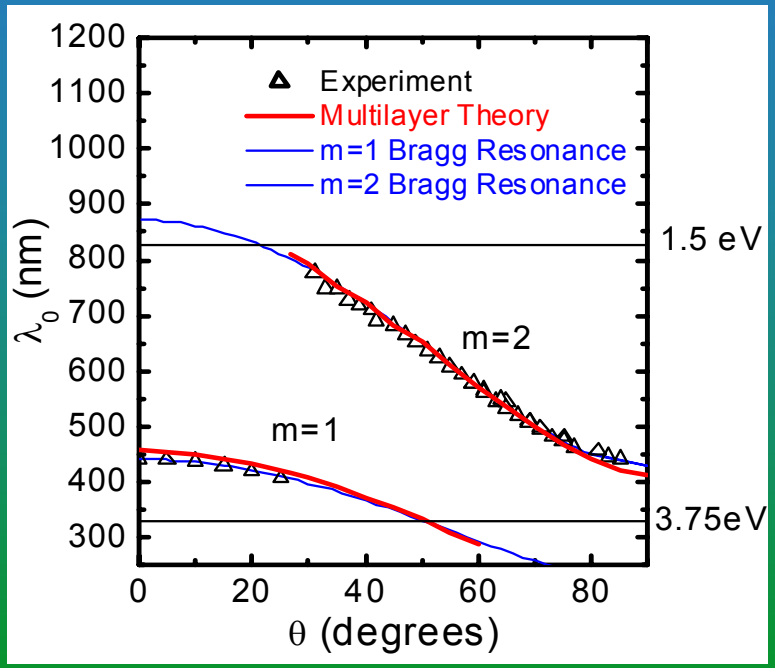


Figure: Wavelength λ_0 of the resonance in optical rotation vs. incidence angle, including experimental data (triangles) and multilayer theory (red lines); also included is the result of a diffraction condition in which λ_0 is assumed to match the projection of *m* pitches onto the light beam direction (blue lines). The MgF_2 chiral film shown above was fabricated by K. Robbie and M. J. Brett of Univ. of Alberta.

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Educational Impact

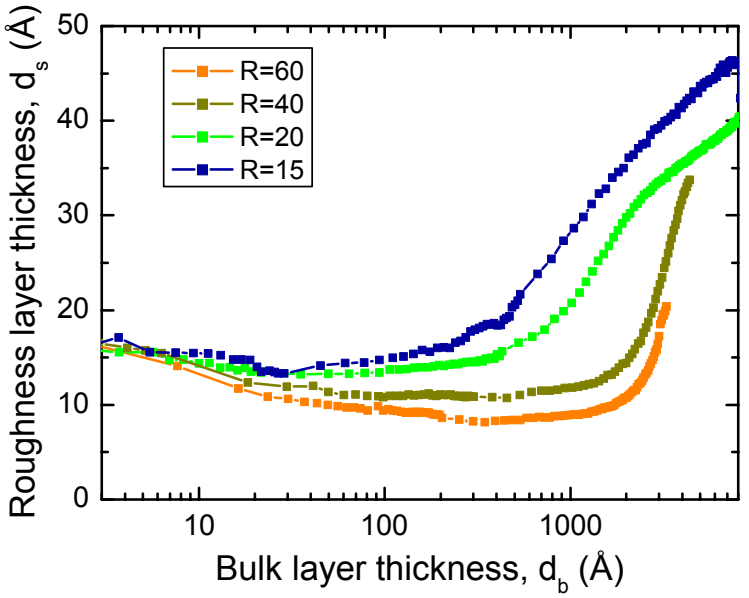
- 3 Undergraduate students (Nik Podraza - REU, Sara Johnson, Scott Thaller),
- 3 Graduate students (Chi Chen, Gelio Ferreira, Anne Lawrence),
- 2 Visiting scholars (Profs. K. Lim - KAIST; I. An - Hanyang Univ.) …

all have participated in the development and application of novel optical instrumentation for fabrication of advanced thin film structures.

Interdisciplinarity, Collaboration, Outreach

This research involves collaborations among faculty in the Depts. of Physics, Electrical Engineering (C. R. Wronski) and Engineering Science (R. Messier). Students have participated in a wide variety of activities from optical instrument development to condensed matter physics to thin-film device development.

Collaborations with photovoltaics industries (BP and United Solar) have led to improved processes derived from basic concepts. The university and local communities have been educated about the importance of clean power generated by inexpensive silicon solar cells.



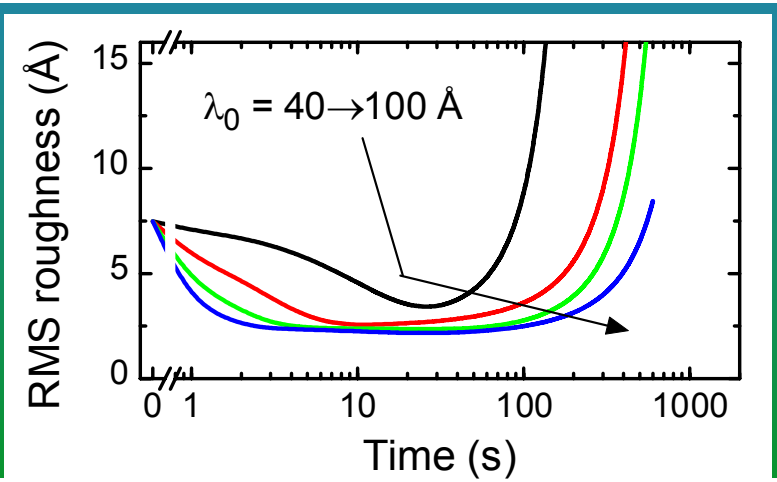


Figure: (Top) surface roughness evolution measured in real time by spectroscopic ellipsometry during the growth of amorphous silicon at different hydrogen dilution levels R=[H_2]/[SiH_4]; (bottom) simulation of film growth from initial nucleation assuming a competition between physical and chemical vapor deposition mechanisms, wherein the surface diffusion length of film precursors λ_0 is varied as shown